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Economic Issues in Standardization

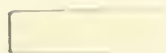
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Management in the 1990s





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ECONOMIC ISSUES IN STANDARDIZATION

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1. Introduction

The subject of compatibility and the economics of standards has become very topical in the telecommunications industry since the AT&T divestiture and with the growing importance of international traffic. Moreover, the introduction of such new services as ISDN and video communications demands a great deal of standardization activity, and offers opportunities for good and bad decisions on standards¹.

Standardization and its problems are not unique to telecommunications. Compatibility may be important even if there is no physical network. For example, one can use nuts and bolts from different manufacturers; one can play the same records on different brands of gramophone, and so forth. It is also easy to list situations in which more compatibility would be useful. International travelers find incompatibilities in language and in electrical outlets, in weights and measures, and in currency. Buyers of Pentax cameras cannot buy lenses from Nikon, and a library of software accumulated for an IBM personal computer is of little value if its owner decides to buy an Apple computer². Other examples are cited in Berg (1985), Farrell and Saloner (1985a,b), Katz and Shapiro (1985a,b).

Such benefits from *doing the same as others do* create economies of scale on the demand side. This raises a number of important economic questions, for example:

1.1 Does standardization retard the adoption of superior new technology?

One may reasonably fear that, when the benefits to compatibility ("network externalities") are important, no user will be willing to be an early adopter of new, incompatible technology since it will be reluctant to lose the benefits of market compatibility. Thus, an industry could get trapped in an inferior technology.

A related issue is the incentives to undertake research and development (R&D) in order to develop a better new technology. Since the market may fail to adopt a superior invention, there are grounds to fear that the incentives to develop inventions will be inadequate.

1.2 When should a standard be set?

Since standardization itself is desirable, early standardization is more desirable than late, if the same standard be set. Early standardization removes the incentive to wait for the standard to settle down, and thus encourages early adoption of the technology. Standardization of interfaces can also open up markets for those who are unable or unwilling to compete with whole systems. However, there are also reasons to wait. Information will flow in that may change our minds about the optimal standard to set. An early choice may be hard to change later.

1.3 Who sets the standards?

In some industries, standards are set by formal industry groups according to well-specified procedures. For example, in telecommunications, the ECSSA and the CCITT have this role. (Of course, different market participants have

different amounts of power in the process). In other industries, an industry leader sets de facto standards. For example, it is generally acknowledged that IBM has standard-setting power in the computer industry. In other cases, buyers get together to demand standardization and even specify standards: see Hemenway (1975), especially chapter 2.

1.4 Can standardization have anticompetitive effects?

(a) Size as an Advantage

Because size confers an advantage in standardization, large firms may have various strategies available that will manipulate the market to their advantage and to their rivals' disadvantage. For example, product preannouncements and standard-switching can become competitive tools.

There are some grounds for concern (see FTC, 1983) that standards, especially design (as distinguished from performance) quality standards, may be used to prevent or discourage entry, particularly entry of new technology.

(b) Essential Facility Questions

What should antitrust policy say about compulsory admission of competitors to a network (multiple listing service in the real estate market, or reservations systems in the airline market)? Because network externalities may produce advantages from market share itself, they may create or extend market dominance. Exclusion from a network may in practice be exclusion from the market. Likewise, we can ask whether dominant firms have an incentive to bias, delay, or sabotage the process of cooperative voluntary standard setting; or whether de facto standards tend to erode, extend or preserve monopoly power.

In this paper, we survey some recent work on question 1 and on the first part of question 4. Question 2 is the subject of some of our current research (Farrell and Saloner, 1985e).

The paper is organized as follows. In Section 2, we discuss some benefits and costs of standardization. In Section 3, we focus on the effects of standardization on the market's willingness to switch from an old to a new technology. In Section 4, we discuss the effects on market structure and competition. In Section 5, we consider the incentives to undertake research and development (R&D) of new technology in a market characterized by compatibility benefits and standardization. Section 6 is a brief conclusion.

2. Benefits and Costs of Standardization

We will describe three types of benefit from standardization: cost savings, competitive effects, and network externalities. We will then mention some social costs that are less obvious than the benefits.

2.1 Benefits of Standardization

2.1.1 *Cost Savings*

By allowing greater scale economies (enabling different manufacturers to exploit economies of scale in using a common supplier), and by allowing the use of interchangeable parts, standardization reduces production costs. This is a staple of economic history; see for instance Landes (1969, 1983), Hemenway (1975)³.

Standardization also saves on the costs of learning how to use a good. For instance, Brock (1975) discusses how pressure for standardization of the programming language COBOL increased when machine time became cheaper relative to programmer time, making it less important to design programs that run efficiently and more important to make it easier to write or transfer programs.

2.1.2 *Competitive Effects*

A common view among economists⁴ is that "plug-compatibility"⁵ does not matter for competition, since there will be competition in any case at the overall systems level. We do not take that view. There will often be barriers to entry at the systems level that would not exist at the components level. For example, consider the market for ski bindings and ski boots. Although there might have been competition among incompatible systems *ex ante*, incompatibility destroys competition *ex post*⁶. Thus, we should recognize that there may be effects of standardization on competition:

- When the products of different makers are standardized, they compete directly in price and performance. Lack of standardization is a form of product differentiation. If variety is mostly "spurious", i.e. does not serve diverse tastes but merely splits the market, then this differentiation is inefficient. If variety is valuable in itself, or if it represents the trying out of different approaches to a problem, then it is not clear whether it is better to have firms compete on price and performance of a standard product, or whether it is better to have them compete on product design.

- Standardization can commit producers to compete in an "aftermarket" for spare or replacement parts, complementary inputs, or peripheral devices. Often, the market for such items (for instance, replacement fenders for a car model) is a natural monopoly, and the original manufacturer (car maker) has an advantage in taking the market (because he makes the original fenders). Absent standardization, this is a possible source of after-sale profits; indeed, in the auto industry, it is notorious that spare parts have a much higher profit margin than cars do. Sometimes such pricing policies are inefficient (for instance, because buyers will inefficiently substitute away from the complementary input), and if that is anticipated by buyers, it may be profitable for the seller (and mutually beneficial) to commit to low or reasonable prices for afterparts. Standardization will achieve this⁷.

- As well as protecting against exploitation from ex-post monopoly, standardization protects against orphaning. If it is perceived that a supplier may go bankrupt, or suffer a crippling strike, buyers will worry about support for their purchases⁸. See for instance Hemenway's (1975) discussion of the auto parts industry before the ASME achieved standardization. Standardization avoids this problem, and thus enhances competition, since a seller no longer

need be seen as both financially secure and committed to the industry in order to sell a product. Sometimes buyers insist on "second-sourcing" to protect themselves against these problems. This is equivalent to guaranteeing (limited) standardization of their selected technology. For instance, in choosing Intel to supply an essential component of the IBM PC, IBM insisted that Intel licence its technology to a second supplier⁹.

- Standardization can help in, or help replace, regulation. Long-distance telecommunications have been (partly) deregulated in the United States by requiring local telephone companies to interconnect with non-AT&T long-distance carriers. Conceivably, some aspects of local telephone service could also be deregulated if switching protocols were standardized and suitable provision were made for interconnections between rival part-networks in the local exchange. The traditional view of telephone service as a natural monopoly is based on the inefficiency of having duplicate networks. This assumes that competing telephone companies would not have interconnection (a form of compatibility). While this may be a plausible result of unregulated competition¹⁰, it is possible that requiring interconnection would make it unnecessary to regulate other aspects of competition.

2.1.3 Network Externalities

Under this heading we group together a number of different effects that make a large "network" of other compatible users desirable.

- A product may simply be more valuable to each buyer the more others have the product. Telephones, of course, are an example. Language is another

example: it is more valuable to speak English, the more other people one comes across who speak English, and indeed we now see English becoming the lingua franca of the world, where French and before that Latin used to be used for international discourse.

- It is more worth learning a skill associated with a product, the more people have the product. (It is worth few people's while, apparently, to learn to type on the Dvorak keyboard, despite considerable absolute efficiency gains: David (1985a) argues that this is due to the network externalities involved.)

- A complementary product may be more readily or more cheaply available as more people have the original product. An example of this is the provision of software for personal computers. The importance of ready availability of a repair network for a product is another example. This network externality was behind much of the success of the Singer sewing machine company in the late 1870s. See Chandler, 1977.

All these benefits make buyers more willing to buy from a seller with either a large market share or compatibility with other sellers. There is thus an incentive for sellers to make their products compatible¹¹. Katz and Shapiro (1985a) discuss the market decision on compatibility when there are costs of making products compatible. Berg (1985) discusses a model in which compatibility makes competition more direct, and firms trade off the gain in value from compatibility against this increase in competition.

2.2 Social Costs of Standardization.

The costs of standardization are less obvious than the benefits. We discuss below the possible loss from reduction in variety. There is also a possible loss from reduced innovation, which we discuss in Section 3.

When tastes differ, standardization involves a tradeoff. We want different tastes to be served; but by hypothesis there are benefits to standardization. There is a considerable literature on the economics of this tradeoff when the benefit to standardization is production economies of scale¹². There has been little work on the corresponding problem when we care about standardization for other reasons, such as the demand-side economies of scale associated with network externalities.

In a simple model (1985c) we can ask the following question. Suppose that there are two types of users, group A and group B, each of whom prefers a different standard. Consider three possible outcomes: both standards could be provided (thus catering to diverse tastes), or only group A's preferred standard could be provided, or only group B's.¹³ We show that there is a tendency for too little standardization, in the following sense: it can happen that the optimum is for a single standard to exist, but the unique equilibrium is for two incompatible standards to persist (one for each type of buyer), while the reverse cannot happen. Intuitively, the externality imposed by one group of buyers on the other is always negative if the first group chooses to be incompatible. However, there can be multiple equilibria, and it is possible for compatibility to be an equilibrium even though the optimum is to have incompatibility and variety. Perhaps in practice this is most likely to be a problem when the need for variety has historically been less important than it be-

comes, so that standardization is the status quo. With more than two groups of buyers, a move by one cannot necessarily be simply described as towards "more" or "less" standardization; the matter then becomes even more complicated¹⁴.

3. Excess Inertia and Excess Momentum

There can be a substantial loss from being on the wrong standard. In a naive sense, this is common: many standards are inferior to the state of the art (we would not choose them if we were designing afresh). It is a more difficult question whether the benefit to switching exceeds the transition costs.

Suppose that there is a status-quo standard, and a new, possibly better, technology appears on the scene. How well does "the market"¹⁵ solve the problem of whether to switch, and if so how quickly?

In Farrell and Saloner (1985a,b) we showed that sometimes the market will not switch even though it should. We called this effect "excess inertia". We also discussed the opposite phenomenon of wrongly abandoning a technology, which we called "excess momentum".

3.1 *Coordination Problems*

In movies of the old West, cowboys who camped for the night where there were no trees to which to tie their horses would often tie the horses to one another. Even though the horses as a group were free to go wherever they

wanted, they would not go far -- whereas a single horse left free overnight would. The horses' difficulty in coordinating on just where they would move at any instant prevented them from moving effectively.

In much the same way, it can happen that an industry may get stuck on an old and inferior technology, even when all participants might prefer to move to a new technology. This happens because the group is "tied together" by reluctance to sacrifice the benefits of being compatible. The fact that it is not only horses who have this problem is shown whenever a group of more than half a dozen people walk from office to restaurant: progress is far slower than with a smaller group.

Consider a model in which each of a number of users chooses (in predetermined order) to switch to a new technology or to stay with the old. Because of network externalities or other benefits of standardization, we assume that each user has preferences over its own choice and others' choices that satisfy a "network externalities" assumption: whatever choice a user makes, it will prefer others to make the same choice. With complete information¹⁶ we showed (1985a) that, if all users would be better off on the new technology, then they will all switch (in the unique perfect Nash equilibrium). If their preferences differ, then the early movers have considerable power to determine the outcome, because of the bandwagon effect. This result (which we called "the New Hampshire Theorem", from the timing of political primaries) comes from our assumption that a user has only one chance to switch; thus, the early movers are Stackelberg leaders. More realistically, whatever makes a user able to commit itself early to a decision on standards will give it power.

However, when we allowed for the fact that preferences are not perfectly known, and studied a model in which each user could choose to switch or

not at each period, we showed that there can be symmetric excess inertia: all prefer the old technology, but none switch. With incomplete information about the benefit of the network externality to others, no user can be sure that it would be followed in a switch to the new technology. This uncertainty can lead all the users to remain with the status quo even when they do all in fact favor switching, because they are unwilling to risk switching without being followed.

Non-binding communication about preferences and intentions eliminates that possibility, but it actually exacerbates the asymmetric problem (if one user would be much better off if both switched, but the other would be somewhat worse off). Thus, there can be socially excessive reluctance to abandon an old established standard. Similarly, "excess momentum" is possible: all users may switch, even though it would be more efficient not to do so.

Thus it takes a substantial preference for the new standard to be an early adopter; and if there are no early adopters then the standard will never be adopted. Excess inertia arises when not enough users are keen enough to go out on a limb with the new technology.

3.2 Installed Base Problems

In the model just described, the only asymmetry between the old and new standard is that a "switch" is more of a commitment than a "stay": not switching is more easily reversible (by switching later) than is switching (switching back is seen as an admission of error, customers will be very displeased, etc.). We now sketch some considerations that arise when the installed base¹⁷ (on the old technology) is important. The analysis is from our 1985b paper.

With an installed base using the old technology, and if network externalities are important, it will be rare for a new technology to be so superior that it will pay for a user to adopt it if he believes that nobody else will. On the other hand, if he believes that everyone else from now on will adopt it, that makes it more attractive and also makes the old standard less attractive. Technically, this means that there may well be two different fulfilled-expectations equilibria. What happens depends purely on what people expect to happen. Naturally, this encourages manipulation of expectations, for instance by strategic forecasting, boasting, or exaggeration of sales figures.

Although the case of multiple equilibria is common and important, the analytical conclusions are more clear cut if there is a unique equilibrium. We can show that there can be a unique equilibrium in which the new technology is ignored but should be adopted, and that in other cases there can be a unique equilibrium in which it is adopted when it should not be.

The reason for this is that each user's adoption decision has two externalities. First, it affects the values of the options available to future adopters. Second, it affects the value of the installed base. The result is that each adopter individually may be either too keen or too reluctant to adopt the new technology.¹⁸

Katz and Shapiro (1985b) study the questions that arise when there is an installed base but also "sponsorship" of one or both technologies, so that sellers may engage in cross-subsidization between early and late users. They show that the market outcome may involve standardization on the "wrong" standard, and may standardize when there should not be standardization.

4. Anticompetitive Practices

Are there anticompetitive practices related to standardization? What, if anything, should be done about them? In this section we report some preliminary analysis on these questions.

4.1 The power of size

Size confers power in the standardization game. The reason is that a large firm does not care much whether its smaller rivals are compatible with it; the smaller firms care much more whether the larger firm is compatible with them. Accordingly, the possibility arises that the large firm can unilaterally set standards for the industry. Both IBM and AT&T are widely believed to have this ability. This advantage is not itself anticompetitive, but it does open up possible anticompetitive strategies. We discuss three below.

4.2 Barrier to Entry

If a small firm or an industry outsider develops an improvement, a large firm may be able to render it valueless by refusing to adopt it. In the standard model, the large firm would be cutting its own throat (at least in the long run) by such behavior; but, with important network externalities, it may be able to ignore others' improvements, or alternatively negotiate very advantageous terms in buying them. For example, Western Union had a strong bargaining position in buying telecommunications patents before the Bell system was developed - though not so strong as it thought when it turned down an offer of

Bell's telephone patent for \$100,000. Obviously, this effect tends to maintain market power, and reduces potential and actual competition. In other words, the network externality creates a barrier to entry. This may well be the most important anticompetitive effect from standards. Below, we discuss some other possible effects.

4.3 Predatory Standard Switching

If a firm that can set de facto standards perceives that its rivals will suffer from making a switch in standard, then its way is open to harm its rivals. Wherever a firm can hurt its rivals, there is the possibility of predation (if re-entry is difficult) and of raising rivals' costs (see Salop and Scheffman, 1983) in any case.

Thus suppose that firm A unilaterally changes its standard. Because A is a dominant firm, buyers expect its new standard to be the standard for the future. Therefore, firm B has no option but to switch to A's new standard. However, this may cause disruption of B's activities. If B is thereby caused to exit the market, then A has effected a predatory reduction in competition. Even if B does not exit, its competitive position relative to A may have weakened¹⁹.

4.4 Product Announcements

One of the alleged anticompetitive practices named in the Justice Department suit against IBM was "premature" product announcement^{20, 21}. In a standard economic framework, it is hard to see how such a practice can be anticompetitive. One would expect (see Fisher et al., 1983) that an announcement of a superior product would be socially beneficial (though detrimental to competitors) while an announcement of an inferior product would have no effect. However, we showed in our 1985b paper that both these views are potentially misleading if network externalities are important. The reason is that the market's solution to the question of whether to adopt the new technology is not necessarily optimal (see also Katz and Shapiro, 1985b) and so the extra information does not necessarily lead to better outcomes. The announcement can be predatory in the sense that the firm that undertakes the action is sacrificing short-run profits in order to cause the exit or failure of a rival, and when it succeeds in doing so it enhances its future profits. Moreover, it is reasonable to expect when installed base is important that future re-entry may be blocked, so that the usual problem in explaining what can be predatory is not present. It is also worth noting that the standard tests for predation may fail to detect the predation. See our 1985b paper.

5. Incentives for R&D

5.1 *Excess Inertia and R&D Incentives*

How does the possibility (discussed above) of excess inertia affect the incentives for research and development (R&D) of new technology? At first glance, it would seem that the influence of excess inertia on incentives for R&D will be straightforward. Even if a firm develops a better system, it is not certain that it will be adopted in the market; this implies that the rewards for R&D are less than they would be without excess inertia. This also means that part of the inefficiency caused by excess inertia is invisible to even the most careful study of inventions not adopted, since presumably many R&D projects never get started (or pursued) as a result of anticipated inertia.

However, that argument is based on considering only one potential innovation. In fact, the return to any innovation is limited by the time when something better still will come along; and this leads to a substantial modification. In a simple model²² we can show that having a higher threshold of minimum successful improvement on existing technology indeed reduces the expected returns to R&D. Intuitively, the barrier harms an innovator now, and helps him later. The help is therefore discounted, and worth less than the harm now.

R&D will be especially discouraged when excess inertia is expected to fall over time, so that the barrier protecting current incumbent technology is higher than that expected to protect anyone who overcomes it.

As the "base" grows over time, inertia will tend to increase²³. Thus the incentive for R&D will be strongest early in the industry history before

the standard gets locked in. Also, the time when a new technology seems to be taking over may be the best time to introduce a further innovation, since the former has no installed base.

5.2 Network Externalities and Licensing of Patents

In a market with important network externalities, there is an extra incentive to licence a patented or sponsored technology. It does not pay for an inventor to keep his new technology to himself. Indeed, it may pay to licence at no charge to some buyers with large volumes but low willingness to pay.

For example, computer makers have been very willing to donate machines to schools and universities.

Another example: Xerox licenced its local area network "Ethernet" at no cost to other suppliers. It presumably intended to ensure that Ethernet would become a standard, and that the originator will have enough of a competitive edge, or the industry is sufficiently uncompetitive, that the originator will make a satisfactory profit from its share of the market for the standardized product.

An alternative strategy of keeping the technology proprietary was followed earlier in the same market by Datapoint, which was unsuccessful. Although a proprietary standard might have been a viable alternative for Xerox, a small firm such as Datapoint had difficulty in establishing it as a standard. On the other hand, of course, the nonproprietary strategy followed by Xerox would have been difficult for Datapoint too, since it might have had less reason to believe it could make satisfactory profits in a nonproprietary market.

5.3 First Mover Advantage and Innovation

The first firm to introduce an innovation often retains a market advantage (price premium, or ability to maintain a large market share) even after others have entered and imitated. While this is in some sense bad for static competition, as it gives (limited) monopoly power to the first mover, it has been argued that such first mover advantages may enhance dynamic or "Schumpeterian" competition by providing something akin to a patent reward for innovation.

We can consider how a first mover advantage affects the analysis of excess inertia in our 1985a paper. It need not be the case that a first mover advantage encourages innovation. The reason is that the first-mover advantage goes together with a second mover disadvantage, and that makes a first mover less likely to be followed in a switch to new technology. Often, innovating is desirable if others follow, but not if they do not. Thus the perceived probability that others will follow is critical to his decision. A second-mover disadvantage makes following an innovator less attractive. This in turn reduces the probability of being followed. This makes innovation less attractive, and this indirect effect can outweigh the direct effect of a first-mover advantage, which is to make innovation more attractive. Thus, first-mover advantage need not encourage innovation. (Note the contrast with the "standard" case without network externalities, in which any reluctance to imitate on the part of rivals merely improves the competitive position of the first innovator.)

6. Conclusion

Standardization is extremely important in modern economies, especially in the information processing industries. While it has many benefits, it may also have serious social costs. There has been little economic analysis of the policy problems.

Conclusions reached by traditional economic reasoning, in which convexity and diminishing returns are generally assumed, are likely to be misleading when bandwagon effects, windows of opportunity for entry, and installed base problems are important. We have seen that the analysis of such staples of industrial organization as pricing, predation, R&D, and the licencing of inventions, is very different when compatibility is important.

There is no easy prescription for microeconomic policy in markets in which network externalities play an important part. In this paper and in our other work, we have identified some of the factors that should be kept in mind, and we have shown how certain standard lessons of economics must be treated cautiously. Further work on the subject is needed.

Footnotes

1. For a general discussion of standards in telecommunications, see Berg (1985).

2. It is sometimes possible to find translation protocols, which, if sufficiently effective, render moot the question of standardization. Such translation, however, is sometimes impossible and is often so difficult that standardization remains important.

3. Cost reductions may be valued by users or by makers (or both), depending on what economists call the incidence of cost savings, which is a matter of market structure. For example, in a perfectly competitive market, all cost savings that reduce marginal costs are passed on to buyers, but cost savings that reduce fixed costs but do not affect marginal costs are not. In imperfectly competitive markets, some cost savings may go to enhance the profits of sellers.

4. For example, Fisher (1979) writes:

To the extent that certain boots are associated with certain bindings...the real competition takes place between binding-boot combinations.

5. We mean this term in a broad sense, to include not only computers and their peripheral devices, but also cameras and lenses, ski boots and bindings, nuts and bolts, autos and fenders, etcetera.

6. See for instance Farrell, 1985.

7. This raises the question of why sellers might resist standardization, given that it enhances the value of their product and also helps towards an efficient selling system. The answer may lie, as Katz and Shapiro (1985a) suggest, in some sort of costs of standardization. Perhaps more plausibly, as Berg (1985) has suggested, standardization somehow makes competition more direct. Thus firms trade off the incentive to maximize the value of their product against the desire to restrain competition. We are also working on this line of inquiry.

8. If a seller is large enough, there may be a presumption that someone would take over these support services, but it is typically not the large sellers that suffer from this fear.

9. In markets with a high (or potentially high) degree of vertical integration, moreover, buyers may not wish to be strategically dependent on a supplier who may later become a direct competitor. Sometimes a user may avoid a de facto standard for this reason: the user fears that the de facto standard setter may exploit his position. Some of the standards decisions of the European community reflect such a concern. For an interesting history of European standards decisions on color television, see Crane (1979).

10. Indeed, some antitrust decisions have suggested that an owner of a network may have an obligation under law (as opposed to regulation) to allow interconnection by competitors, if the network becomes an "essential facility".

11. If it is technically feasible, which it sometimes is, a seller would always wish to have one-way compatibility: his buyers get the advantages of the whole network, while other firms' customers only get the externalities associated with their small networks. A classic case of this is the competition that led to the strange-shaped holes in the safety razor blades that dominated the market until the seventies.

12. For example, see Dixit and Stiglitz (1977), or Spence (1976).

13. For a discussion of the possibility of compromising on the standard, see Berg (1985).

14. For another analysis of standardization with differences in tastes over standards, see Berg (1985). The work of Katz and Shapiro (1985b), and Farrell and Saloner (1985b), although not explicitly about the efficiency-variety tradeoff, can be interpreted in those terms. They analyse the evolution of standards over time when buyers at different times have different preferences or different opportunities.

15. We focus on what Arthur (1984) has called "non-sponsored" technology. That is, there is no owner of the new (or the old) standard who can subsidize early adopters in order to get a new standard rolling. Interesting questions arise (Katz and Shapiro, 1985b, Hanson, 1985) if the technology is sponsored, and also if, while the new standard would not be owned, its early developer would have a substantial first-mover advantage if it succeeds. (We briefly treat the question of first-mover advantage below.)

16. This term means that each decisionmaker knows the preferences of all others, and everyone knows that, etc.

17. Sometimes the installed base will be physical capital; in other cases the human capital invested in training on the old system will be more important. The typewriter keyboard case (David, 1985a) is an interesting intermingling of the two.

18. A related problem (without the dynamics) is the problem of uneconomic bypass in telephone markets. It is widely predicted that, if pricing is constrained by uniformity requirements, bypass will become very popular and will reduce the value of being on the network (here, for cost-sharing reasons) to such an extent that the bypass is socially inefficient. Again, an autarchic technology may reduce the value obtained from a network technology; again, this would not happen if pricing were not constrained.

19. We will not speculate here on whether any particular standard switch is predatory. However, Brock (1975) describes the announcement of IBM's System 360 in terms that suggest such an interpretation. Honeywell had announced a computer known as the H-200, together with a translator device (called the Liberator) making it compatible with the IBM 1401. This combination competed directly and favorably with IBM's 1401 machine, which was then the market leader. IBM's System 360, which was announced shortly after Honeywell's announcement, was incompatible with the 1401 and the H-200, and yet (whether because the 360 was superior, or because of IBM's reputation as a de facto stan-

standard setter) customers chose to wait for the 360, thus destroying the commercial viability of the H-200.

20. See allegations in *California Computer Products Corp. v IBM Corp.*, 613 F. 2d 727 (9th Cir. 1979), *Memorex Corp. v. IBM Corp.*, 636 F. 2d 1188 (9th Cir. 1980), and see also *Berkey Photo Co. v. Eastman Kodak Co.*, 457 F. Supp. 404 (S.D.N.Y. 1978), 603 F. 2d 262 (2d Cir. 1979) and 444 U.S. 1093 (1980).

21. IBM's rivals have also complained about insufficient advance notice of IBM's changes in its (and de facto industry) standards. Evidently, firms that depend on following the lead of a de facto standard setter are at a competitive disadvantage if they learn about standard shifts only late in the day. IBM has agreed to announce standard shifts in advance, as a result of an EEC antitrust action.

22. Details available on request.

23. This may account for some "waves of innovation": no sooner does innovation A start to succeed than innovation B pushes it out of the way; in contrast to other industries in which there has been no innovation in many years. It may also account for the tremendous economic growth sometimes observed after wartime destruction of the capital stock. Once a large fraction of the existing stock is destroyed, there is (or can be) a general expectation that new techniques can profitably be put in place. See Shleifer (1985) for a business-cycle model related to this observation.

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